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(54) IMPROVEMENTS IN OR RELATING TO ULTRAVIOLET CURING SYSTEMS

(71) We, APPLIED PHOTOPHYSICS LIMITED, a British Company, of 20 Albemarle Street, London, W.1, England and MICHAEL ANTHONY WEST, a British Subject, of Applied Photophysics Limited, 20 Albemarle Street, London, W.1, England, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement: —

The present invention relates to methods and apparatus for curing materials by ultraviolet radiation. The invention is particularly applicable to the curing of materials, such as printing inks, roller coatings, varnishings and other coating materials, which are formed as a coating on an object and cured while the object is moving.

For some time, conventional printing inks which were printed on metal and to a limited extent paper, etc. were cured by the use of thermal driers. More recent developments have used continuous mercury lamps emitting ultraviolet radiation to cure the inks. This curing is effected by polymerization and the inks require suitable photo initiators in the composition of the ink to cause polymerization in response to the ultraviolet radiation. However, continuous mercury lamps have a number of limitations. For instance, the radiation emitted has a line spectrum so that the photo initiators used in the inks have to be selected so as to respond to the particular wavelengths in the mercury spectrum. Furthermore, the mercury lamps produce ozone which can be harmful to people and materials in the environment of the apparatus. Furthermore, the mercury lamps generate considerable heat and require a considerable amount of energy for their operation.

It is an object of the present invention to provide an improved method and apparatus for curing materials, such as printing inks by ultraviolet radiation, the radiation being derived from one or more inert gas flash lamps. Such flash lamps can be operated by pulsed discharge to provide short duration pulses of radiation with high peak intensity and a continuous emission spectrum in the ultraviolet region.

The present invention provides a method of curing, by ultraviolet radiation, material such as for example a roller coating or printing ink, which is formed as a coating on a movable article, which method comprises conveying a succession of articles bearing material to be cured past a curing station and irradiating the material with a short duration pulse of ultraviolet radiation at the station by operation of at least one inert gas flash lamp, the ultraviolet radiation being derived solely from one or more flash sources and the time of discharge of the or each lamp being synchronised in timed relationship with the arrival of an object at the curing station so that curing is effected while the objects are moving.

In this way, the or each flash source operates at a rate determined by the rate of arrival of the objects at the curing station.

Preferably the arrival of each article at the curing station is detected and used to generate a signal which in turn is used to control operation of the or each flash lamp. In this way, the or each flash lamp operates only when an article arrives at the station.

Preferably each article is detected before reaching the or each flash lamp and the signal generated by detection of the article is delayed by a predetermined amount before operating the or each flash lamp.

Preferably the ultraviolet radiation is derived from one or more xenon flash lamps. The xenon flash lamps may be energised by a relatively low voltage, e.g. in the range 1 kv to 5 kv.

The method may comprise moving the article bearing material to be cured past a source of ultraviolet radiation comprising solely two or more inert gas flash lamps and

irradiating the material with short duration pulses of ultraviolet radiation by successive operation of the flash lamps.

Preferably, in such an arrangement the flash lamps are arranged to be operated with a distinct interval between the end of one flash and the beginning of the next.

Preferably the first and second flashes have different durations and preferably different spectral properties. The first flash may, in some cases, be arranged to be of longer duration than the second flash.

Conveniently the energisation voltage is stored in a capacitor charged by a D.C. supply. The D.C. supply may be derived by simple multiplication and rectification of a multiphase A.C. voltage supply.

Preferably the or each flash lamp is formed in a shape which conforms to the shape of the or each article on which the said material is coated.

Preferably the dimensions, internal gas pressure, operating voltage and other electrical parameters of the or each flash lamp are chosen to provide an emission spectrum which is the most suitable for the particular material to be cured.

The invention includes passing an article through two or more curing stations in succession, additional material to be cured being applied to the article intermediate two curing stations.

The invention also includes apparatus for curing, by ultraviolet radiation, material such as for example printing ink which is formed as a coating on a movable article, which apparatus comprises a curing station having a source of ultraviolet radiation comprising solely one or more inert gas flash lamps, conveying means for conveying a succession of articles bearing material to be cured through said curing station, detector means arranged to detect the arrival of each article at said curing station and provide an output signal, and control means arranged to receive said output signal and control the operation of the or each flash lamp in synchronism with the arrival of the objects at the curing station.

The source of ultraviolet radiation may comprise solely two or more inert gas flash lamps, the control means being arranged to operate each flash lamp so that the lamps are operated in sequence when the material to be cured is adjacent the lamps.

Preferably the or each flash lamp comprises a xenon flash lamp arranged to provide a short duration high intensity pulse of radiation due to discharge of stored electrical energy.

Preferably the or each flash lamp is connected to an electrical energisation supply arranged to provide a relatively low voltage between 1 kv and 5 kv. The voltage may be between 1 kv and 1·3 kv.

The invention includes apparatus for applying printing ink to a succession of articles in combination with apparatus for curing the printing ink as aforesaid. The apparatus may include one or more stations for applying printing ink each being followed by a curing station whereby a plurality of ink coatings may be applied and cured in succession.

Some embodiments of the invention will now be described by way of example and with reference to the accompanying drawings in which: —

Figure 1 is a schematic side view of one roller coating apparatus in accordance with the present invention,

Figure 2 is a block diagram showing in more detail some of the components used in Figure 1,

Figure 3 shows a view similar to Figure 1 of a printing arrangement in accordance with the present invention,

Figure 4 shows a modification of the arrangement shown in Figure 1 using two flash lamps at the curing station,

Figure 5 shows a power supply for a flash lamp which may be used in the arrangements of Figures 1, 3 or 4, and

Figure 6 shows an alternative power supply for a flash lamp used in the arrangements of Figures 1, 3 or 4.

In Figure 1 an arrangement is shown which is suitable for applying a coating of photo polymer material to an article in sheet form and subsequently curing the material by irradiation with ultraviolet radiation. The example is particularly applicable to the application of roller coatings to metal, paper or plastic sheets or webs. In the particular arrangement shown a stack of metal or card sheets 11 is shown at the left-hand side of the drawing and the sheets are transferred by known sheet handling apparatus (not shown) so that the sheets pass onto a conveyor 12 and are conveyed at a uniform speed through a printing station 13 followed by a curing station 14. The conveyor 12 then unloads the metal sheets (by means not shown) into a collecting station 15. At the printing station 13, two co-operating rollers 16 and 17 provide a pass through which the metal sheets are conveyed and the roller surfaces apply roller coating to the metal sheet on passing between the rollers. The curing station 14 is preceded by a sheet detector 18 comprising a light source 19 and a light detector 20. When the leading edge of a sheet passes between the light source 19 and detector 20, light received by the detector 20 is abruptly cut off and this provides a signal along line 21 which is fed to a control unit 23 within the curing station 14. The station 14 also includes one pulsed xenon discharge lamp 22 connected to the

control unit 23. The lamp 22 is arranged to provide a short duration high intensity pulse by rapid discharge of stored electicity. This is explained more fully with reference to Figure 2. The flash of radiation from the lamp 22 provides a continuous emission spectrum in the ultraviolet region. The lamp and its control circuit are arranged to provide sufficient energy in the correct wavelength region to activate the photo initiator in the photo polymer coating material so that the roller coating is cured on passing through the curing station 14. The sheets leaving the station 14 pass into the collector unit 15 with roller coating which has been suitably dried. Some of the components used in the curing station of Figure 1 are shown more fully in Figure 2.

The sheet 11 carrying the roller coating to be dried passes between the light source 19 which in this case consists of a light emitting diode and the detector 20 which consists of a light activated switch of known type. The switch 20 is connected to a positive D.C. source 24. The output from the switch 20 is fed along line 27 through a time delay generator 28 and pulse shaping monostable circuit 29 to the gate electrode of a thyristor 30. The thyristor is connected between a 300 volt positive supply 31 and earth. A capacitor 32 takes a signal from a point between the thyristor 30 and the supply 31, and the output from capacitor 32 discharges through the primary of a high voltage trigger transformer 33. The secondary output of the transformer is supplied to a spark gap device 34 connected between one terminal of the flash lamp 22 and an earth connection 35. The other terminal of the lamp 22 is connected to a discharge capacitor 36 and a high voltage power supply 37 arranged to charge the capacitor. When no object 11 is between the light emitting diode 19 and switch 20, the spark gap 34 is not triggered so that the discharge capacitor 36 is charged up from the power supply 37 without operation of the flash lamp 22. However, when an object interrupts the light incident on the switch 20, an output signal is fed along line 27 which causes a pulse to be fed to the spark gap 34 thereby triggering the spark gap to cause discharge of the capacitor 36 through the flash lamp 22. This causes a short duration high intensity radiation pulse from the lamp 22 and the variable delay introduced by the generator 28 is suitably matched to the operating times of the other electrical components to result in the radiation flash from the lamp 22 coinciding with arrival of the article 11 in the curing station 14 adjacent the lamp 22. In this way, the lamp 22 is not operated unless an object 11 arrives at the curing station and the rate of operation of the lamp 22 is determined by the rate of arrival of objects at the curing station.

With regard to the high voltage power supply 37, this is arranged to provide a D.C. voltage in the range 1 kv to 5 kv. In order to avoid a conventional high voltage D.C. power supply, it is preferable to use for the supply 37 a three-phase A.C. supply, each phase providing 440 volts, together with means for multiplying, e.g. doubling, tripling or quadrupling the voltage and voltage rectification to achieve the desired D.C. voltage level.

Figure 3 shows an arrangement used for printing more than one colour onto a succession of metal or non-metal sheets. Parts similar to those already described with reference to Figure 1 are marked with the same reference numerals. In this case, the apparatus includes two successive printing stations 13*a* and 13*b* followed by respective curing stations 14*a* and 14*b*. In this way, a first colour ink is applied at the printing station 13*a* and subsequently dried by the curing station 14*a*. A second ink is then applied at printing station 13*b* and dried at curing station 14*b* before passing to the collecting unit 15. In this particular example, each printing station is shown as an off-set printing machine.

In Figures 1 and 3 each curing station includes only one flash lamp 22. However two or more flash lamps may be used at each curing station although no non-flash sources of ultraviolet radiation are included in a curing station. Figure 4 shows a modification of the arrangement of Figure 1 using two flash lamps 22*a* and 22*b* at the same curing station. Similar reference numerals have been used for parts similar to those in Figure 1. In this case, the coating station has two flash lamps 22*a* and 22*b* spaced apart along the direction of travel of the article and arranged to provide flashes of different durations and different spectral properties. The two lamps are surrounded by respective housings 14*a* and 14*b* which are separated from each other. Each lamp is of the same general type as already described with reference to Figure 1 although the lamps may in this case be from six inches to four feet long and may be operated by voltages from 1 kv to 25 kv.

The lamp 22*a* which is located at an upstream position and is operated first may have a longer flash duration which may be of the order of 100 to 1000 mciroseconds. The downstream lamp 22*b* which is operated after a time interval may have a shorter flash duration which may be of the order of 10 to 800 microseconds. The interval between termination of the first flash and initiation of the second flash may be of the order of 1 millisecond up to 10

seconds. Lamp 22a which is operated first is arranged to operate with a lower black body temperature so that more infrared and less ultraviolet radiation is emitted than is the case with the flash lamp 22b which follows.

The two flash lamps 22a and 22b are operated from a common control circuit 23 incorporating a suitable delay mechanism for firing the second lamp 22b. The extent of delay is preferably variable by an adjustable control in the control circuit. The control circuit may be similar to that of Figure 2 in that the arrival of an object can be detected by the common switch 20. The delay generator 28 may be arranged to provide two output signals each having a different and adjustable delay. The two output signals can then be fed to two separate firing circuits similar to that of Figure 2, each firing circuit being associated with one of the lamps. In this way, both flash lamps are synchronised with the arrival of one object and from then onwards the flash lamps are operated at timed intervals which are arranged to suit the curing operation.

Figure 5 shows an alternative power supply and triggering system for a flash lamp and may be used for the single lamp 22 or for either of the lamps 22a or 22b. In this case, the power supply system 37, which may be the same as previously described with reference to Figure 2, is connected across the discharge capacitor 36 via a resistor 38. The capacitor 36 is connected across the main terminals of the flash lamp 22 via an inductance 39. The lamp 22 is surrounded by an external ionizing coil 40 which is wrapped around the lamp. The coil 40 is connected through a centre tapped transformer 41 to an external trigger supply terminal 42. When a suitable trigger pulse is supplied from the terminal 42, the resultant ionizing current in the coil 40 causes rapid discharge of the capacitor 36 through the lamp.

An alternative power supply for any one of the flash lamps which provides greater light output per flash and a longer lamp life is shown in Figure 6. In this case, the capacitor 36 is charged through a resistor 38 by the power supply 37. To produce a light flash, the capacitor 36 is discharged through the inductance 39 and through the lamp 22. In this case a spark gap 44 is connected in series with the inductance 39 and the trigger electrode 45 of the spark gap 44 is arranged to receive signals indicating the arrival of an object at the curing station. The coil 40 surrounding the lamp 22 is connected through a transformer 46 to a pulse generator 47 which is used to cause initial ionization of the lamp by an external trigger source. In this arrangement shown in Figure 6, the lamp 22 is also connected across a D.C. power supply 48 which causes a steady low power D.C. discharge through the lamp in the intervals between the rapid discharge causing flashes. This steady pre-ionization caused by the D.C. power supply 48 causes a greater light output per flash from the lamp 22 for a given energy discharge through the lamp and it also gives longer lamp life. As an alternative to the arrangement shown in Figure 6, the steady pre-ionization caused by low power D.C. discharge may be achieved in other ways. Instead of using the D.C. supply 48 in series with the lamp 22 it is possible to use an external ionizing coil wrapped around the lamp or alternatively an ultraviolet lamp may be arranged to shine onto the flash lamp thereby producing a steady low ionization state within the lamp 22.

Although the above examples have referred to the use of xenon filled flash lamps, other inert gases may be used. The lamp dimensions, gas pressure, flash duration, operating voltage and other electrical parameters are chosen to give an emission spectrum which is the most suitable for the particular materials being cured. In one example suitable for use in the arrangement of Figure 1, a cylindrical linear lamp with inert electrodes is mounted in a semicylindrical reflector. The lamp may be six to nine inches long having a bore of ¼ inch to ½ inch. The lamp is operated between 1 kv and 3 kv with output energies of 200 to 500 Joules per lamp. The gas filling the lamp may be at one to ten millimetres of mercury pressure and the gas used may be xenon, or krypton or a xenon/krypton mixture or a xenon/hydrogen mixture.

The invention is not limited to the details of the foregoing examples. For instance, the lamp shape can be varied and made to conform to the shape of the objects carrying the ink to be dried. For instance, when curing ink on cylindrical metal objects, helical lamps may be used to cure the ink on the exterior of the cylindrical object and a linear cylindrical lamp may be used to cure ink on the interior of the object. When more than one lamp is used at a curing station, the lamps at the station may be fired simultaneously.

One or more of the lamps may be used in the simmer mode. In that case, a continuous or pulsed low current discharge is passed through the lamp to pre-ionize the gas filling. This results in low level of light emission and the main flash is still obtained by discharge of the capacitor through the lamp. Use of the simmer mode as the advantages of higher ultraviolet output and longer lamp life.

In this specification, the term flash source means a source of ultraviolet radiation

which emits effective radiation (that is of sufficient intensity to effect curing) only in short duration pulses. In between the effective pulses of radiation the flash source may emit a low level of continuous or pulsed emission which is not sufficient to effect curing, such as for example when operated in a simmer mode.

WHAT WE CLAIM IS: —

1. A method of curing, by ultraviolet radiation, material such as for example a roller coating or printing ink, which is formed as a coating on a movable article, which method comprises conveying a succession of articles bearing material to be cured past a curing station and irradiating the material with a short duration pulse of ultraviolet radiation at the station by operation of at least one inert gas flash lamp, the ultraviolet radiation being derived solely from one or more flash sources and the time of discharge of the or each lamp being synchronised in timed relationship with the arrival of an object at the curing station so that curing is effected while the objects are moving.

2. A method according to Claim 1 wherein the arrival of each article at the curing station is detected and used to generate a signal which in turn is used to control operation of the or each flash lamp.

3. A method according to Claim 2 wherein each article is detected before reaching the or each flash lamp and the signal generated by detection of the article is delayed by a predetermined amount before operating the or each flash lamp.

4. A method according to any one of Claims 1 to 3 wherein ultraviolet radiation is derived from one or more xenon flash lamps.

5. A method according to any one of Claims 1 to 4 wherein the article is moved past a source of ultraviolet radiation comprising solely two or more inert flash lamps, and the material to be cured is irradiated with short duration pulses of ultraviolet radiation by successive operation of the flash lamps.

6. A method according to Claim 5 wherein the flash lamps are operated with a distinct interval between the end of one flash and the beginning of the next.

7. A method according to Claim 6 wherein the first and second flashes have different durations.

8. A method according to Claim 6 or Claim 7 wherein the first and second flashes have different spectral properties.

9. A method according to any one of the preceding claims wherein the or each flash lamp is energised by charging a capacitor by multiplication and rectification of a multi-phase A.C. voltage supply and then discharging the capacitor.

10. A method according to any one of the preceding claims in which the article is passed through two or more curing stations in succession, additional material to be cured being applied to the article intermediate two curing stations.

11. Apparatus for curing, by ultraviolet radiation, material such as for example printing ink which is formed as a coating on a movable article, which apparatus comprises a curing station having a source of ultraviolet radiation comprising solely one or more inert gas flash lamps, conveying means for conveying a succession of articles bearing material to be cured through said curing station, detector means arranged to detect the arrival of each article at said curing station and provide an output signal, and control means arranged to receive said output signal and control the operation of the or each flash lamp in synchronism with the arrival of the objects at the curing station.

12. Apparatus according to Claim 11 wherein the source of ultraviolet radiation comprises solely two or more inert gas flash lamps, the control means being arranged to operate each flash lamp so that the lamps are operated in sequence when the material to be cured is adjacent the lamps.

13. Apparatus according to Claim 11 or Claim 12 wherein the or each flash lamp comprises a xenon flash lamp arranged to provide a short duration high intensity pulse of radiation due to discharge of stored electrical energy.

14. Apparatus according to any one of Claims 11 to 13 wherein the or each flash lamp is connected to an electrical energisation supply arranged to provide a relatively low voltage between 1 kv and 5 kv.

15. Apparatus according to any one of Claims 11 to 14 wherein the or each flash lamp is formed in a shape which conforms to the shape of the or each article on which the said material is coated.

16. Apparatus according to any one of Claims 11 to 15 in combination with means for applying ink or coating material to the article.

17. Apparatus according to any one of the preceding claims in which one or more of the lamps is operated in the simmer mode.

18. A method of curing printing ink or roller coating on an article, which method is substantially as hereinbefore described with reference to any one of the accompanying drawings.

19. Apparatus for curing printing ink or roller coating on an article, which apparatus is substantially as hereinbefore described with reference to any one of the accompanying drawings.

Agents for the Applicants:
PAGE, WHITE & FARRER,
Chartered Patent Agents,
27 Chancery Lane,
London WC2A 1NT.

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4 SHEETS This drawing is a reproduction of the Original on a reduced scale

Sheet 1

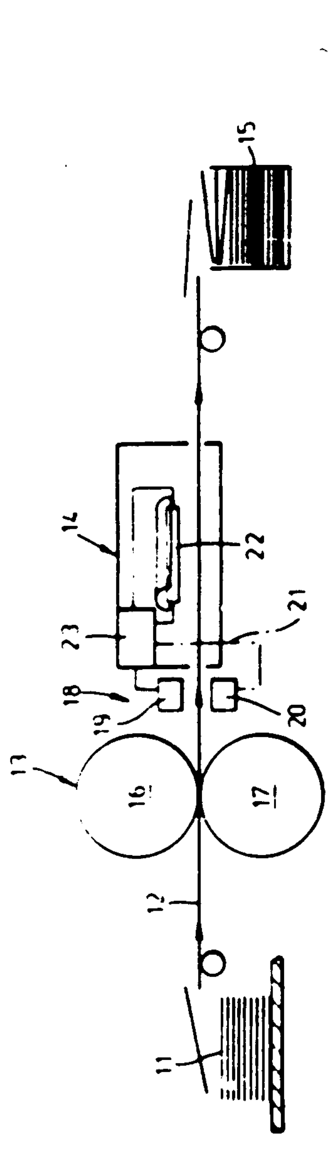


Fig.1

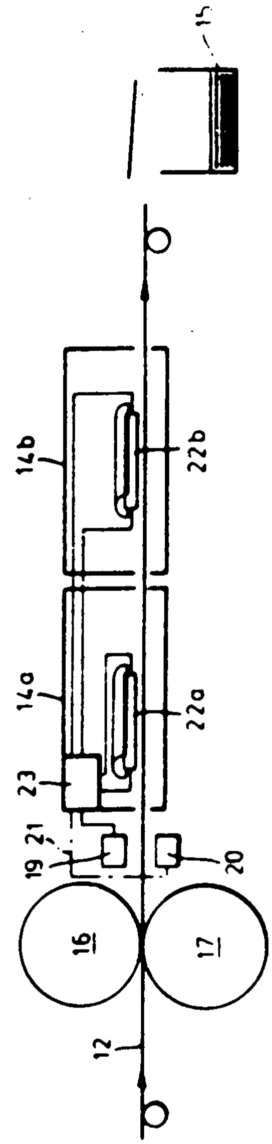
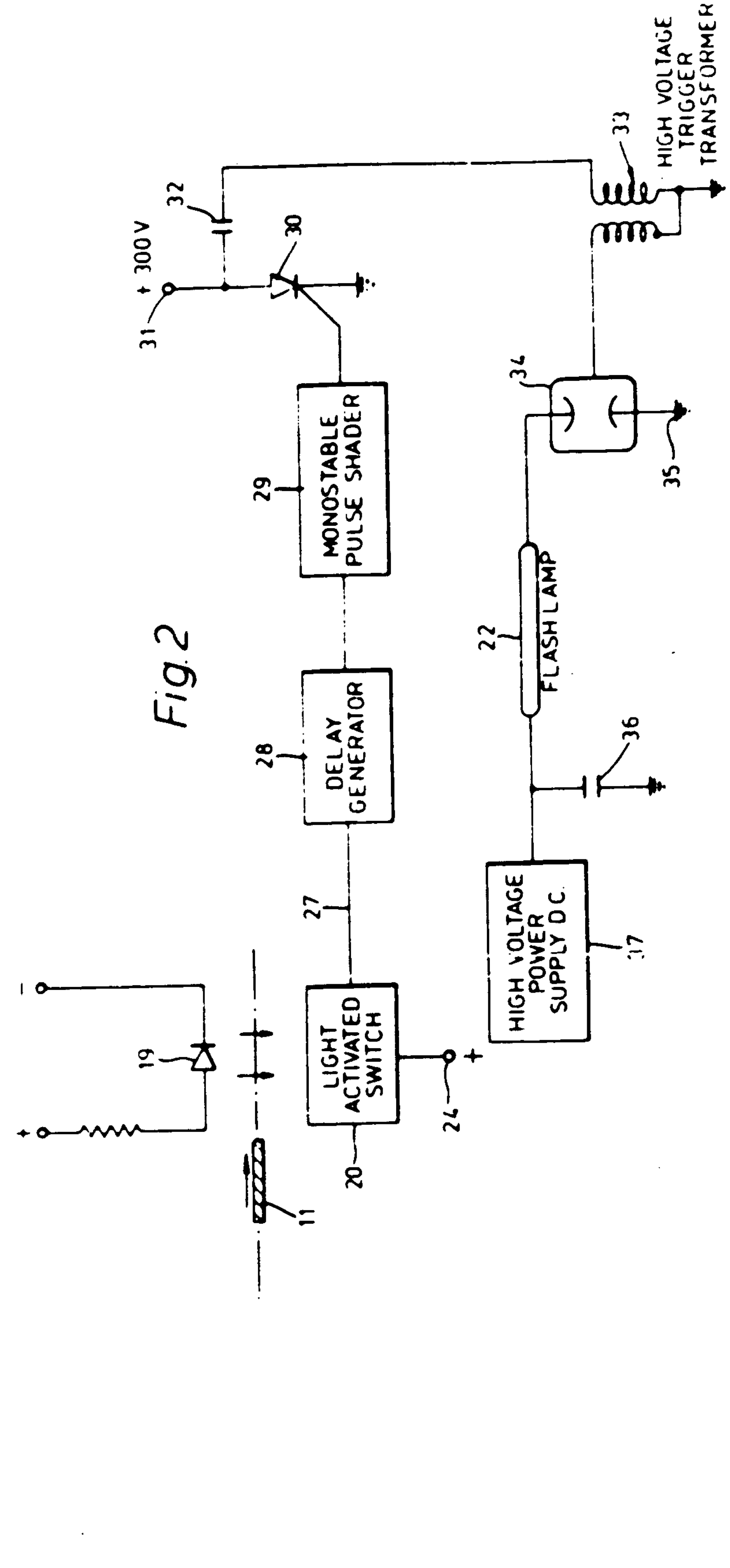


Fig.4


HIGH VOLTAGE TRIGGER TRANSFORMER
33
32
+ 300V
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30
MONOSTABLE PULSE SHADER
29
DELAY GENERATOR
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27
LIGHT ACTIVATED SWITCH
20
19
11
24
34
35
FLASH LAMP
22
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HIGH VOLTAGE POWER SUPPLY D.C.
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Fig. 2

1581998 COMPLETE SPECIFICATION

4 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 3

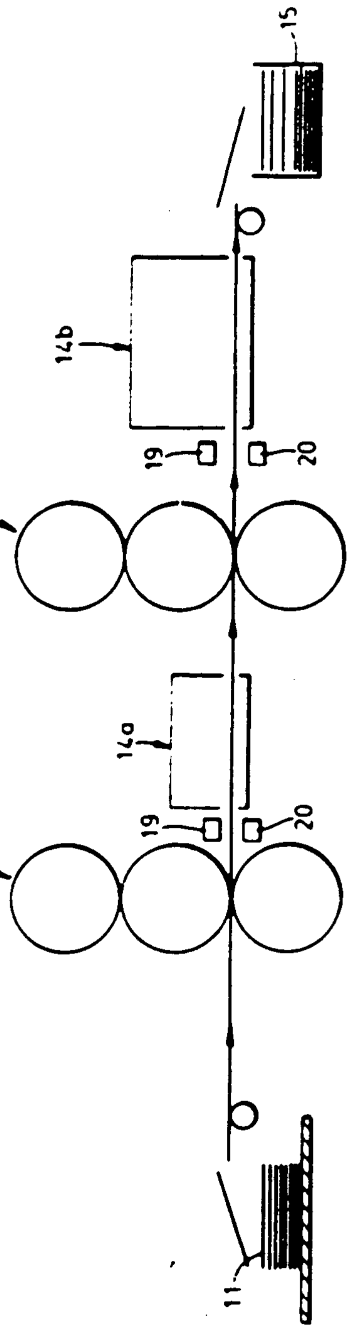

Fig. 3

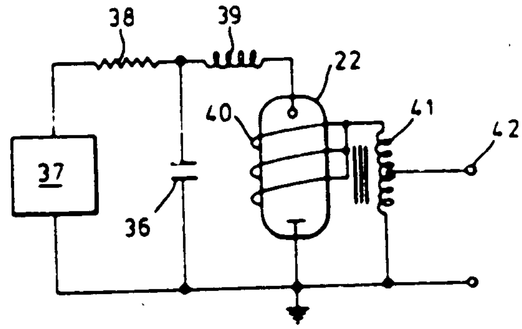
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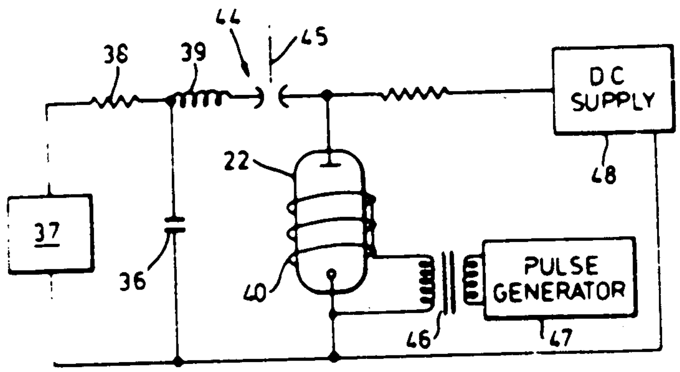
Fig.5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DC SUPPLY
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PULSE GENERATOR
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Fig.6